Chapter 5

Evaluation of GNSS Data with Internet Based Services: The Case of HRUH Station

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.79064

Abstract

Nowadays, as the Internet services are developed, it becomes possible to offer services for many applications in the engineering field online via the Internet. One of these services is the evaluation of online GPS data. The most important feature of Internet-based applications is that these services are free and easy to use. In this study, the data of Global Navigation Satellite Systems (GNSS) of different periods belonging to newly established HRUH permanent GNSS station in Harran University were evaluated through Internet-based services. The evaluation strategy of GNSS data was conducted in 1-, 2-, 6-, 12-, and 24-h campaigns, and the results were compared between different Internet site solution results. When the results obtained are examined, it can be said that the accuracy of the data obtained from these services can be used in many applications requiring precision in centimeter levels and is capable of satisfying the expectancies.

Keywords: PPP, GNSS, RINEX, internet-based GNSS evaluation services, positioning accuracy

1. Introduction

Recently, web-based GNSS positioning services have begun to be developed as an additional option to classical evaluation methods. Such services produce solutions automatically by using some of the GNSSS observations loaded via the web interface over the Internet. GNSS observations collected in the field are recorded in standard data formats such as Receiver INdependent EXchange (RINEX) and then uploaded to web-based positioning services, allowing location coordinates of observation points to be obtained in short time and free of charge [1–3].

Web-based positioning services have been considered as an alternative to scientific or commercial software for 15 years. Wherever the Internet access is available, it is easier to evaluate RINEX data using such services. Another reliable aspect of preferring web-based GNSS software is the use of reliable scientific software (Bernese, Gamit, GIPSY/OASIS II, etc.) running in the background of these systems. These services also provide many advantages to the user by reducing the cost of many software, hardware, tools, personnel and transportation services. The results of evaluations of GNSS observations uploaded to these services also provide many advantages such as the possibility of downloading results from the web interface or sending the results to the users via e-mail. The results from these services are in the form of a summary or detailed report. The standard deviation values of these points are sent together with the estimated point coordinates in the incoming reports. Some services send out summary reports in the form of short summary information, while some services provide detailed reports with detailed and graphical presentations. Many of these services are free and some of them require free membership for accessing with a user name and password while using. In general, these services use the data and products of the high accurate and precise International GNSS Service (IGS). IGS provides these products with high precision of GPS/GLONASS ephemeris, satellite and station clocks, earth orientation parameters (ERP), IGS stations coordinates and velocities, and atmospheric parameters to users. These services provided by IGS have led to the emergence of new approaches and new evaluation methods in positioning with the accuracy increase in data processing, orbit determination, and acquisition of clock information in satellite geodesy [4].

Web-based positioning services have introduced two different types of solutions. The first is the relative positioning approach and the second is the precise point positioning (PPP) solution approach. In this study, web-based precise point positioning solution will be mentioned. The services that are mainly used for the PPP solution approach use only GPS or GPS + GLONASS products such as orbits and clock corrections. The data flow for both web-based positioning services is shown in **Figure 1**.

In this study, four different web-based PPP services, which are most well known and widely used, general properties of services, accessing addresses and analysis results are examined.

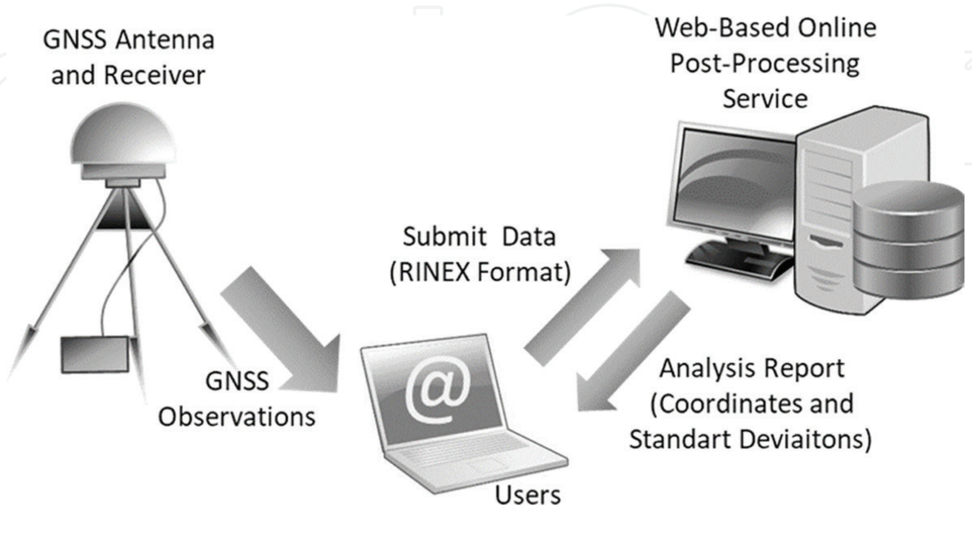

Figure 1. Schematic presentation of web-based positioning services.

1-, 2-, 6-, 12-, and 24-h GNSS observations of the HRUH permanent GNSS station which is established on the roof of the GNSS Laboratory of Harran University Geomatics Engineering Department are evaluated for each web-based positioning service. Then, the same GNSS observations of this station are compared with the analysis results (coordinates and standard deviations) with the scientific GNSS-Inferred Positioning System and Orbit Analysis Simulation Software (GIPSY/OASIS II) developed by NASA's JPL laboratory.

2. Precise point positioning (PPP)

The widespread use of satellite and space techniques has become an indispensable tool in satellite positioning. Nowadays, by using developed techniques and methods, highly accurate position information is obtained with the help of positioning algorithms. These techniques often differ according to the data collection method. Absolute and relative positioning methods from the earliest times of use of positioning systems are the most preferred techniques for application purposes. The relative positioning technique requires at least two receivers to be used by simultaneous GNSS observations. However, PPP is a method that can be applied by removing this necessity. The PPP technique is based on the evaluation of the code and phase measurements collected from a single receiver. In this technique, the receiver position is directly determined by using precise orbits and clock corrections issued by IGS and similar organizations [5, 6]. The success of the positioning with the PPP technique depends largely on the determination of precise orbit changes of GPS satellites. Therefore, in PPP solutions, it is important to obtain precise orbit (ultra-rapid, rapid, and final) and satellite clock information instead of orbital information broadcast from satellites. Accuracy, broadcast latency, update and sample interval for accurate GPS satellite orbits and clock corrections published by IGS are given in **Table 1**.

Nowadays, as the accuracy of precise satellite orbits and clock products published by organizations such as IGS, CODE, and JPL advances, the use of PPP technique is gradually increasing in determining the point positions.

The ionosphere-independent observation equations of pseudorange and carrier phase measurements include receiver location, clock offset, tropospheric delay, carrier phase unknown parameters, and observation errors:

$$\begin{aligned} l_p &= \rho + c(dt - dT) + T_r + I_r + \varepsilon_p \\ l_\varphi &= \rho + c(dt - dT) + N\lambda + T_r + I_r + \varepsilon_\varphi \end{aligned} \tag{1}$$

where l_p and l_φ are the ionosphere-independent combination of the code and phase measurements, respectively; dt is the receiver clock offset which is the difference between receiver time (receiver clock) and system time (GPS); dT is the satellite clock offset which is the difference between satellite time (satellite clock) and system time (GPS); c is the speed of light in space; N is the integer ambiguity of the ionosphere-independent carrier phase; T_r is the tropospheric signal delay, and I_r is the ionospheric signal delay between the satellite and the receiver; λ is

Type		Accuracy	Latency	Updates	Sample interval
Broadcast	Orbits	~100 cm	Real time	---	Daily
	Sat. clocks	~5 ns RMS ~2.5 ns SDev			
Ultra-rapid (predicted)	Orbits	~5 cm	Real time	At 03, 09, 15, 21 UTC	15 min
	Sat. clocks	~3 ns RMS ~1.5 ns SDev			
Ultra-rapid (observed)	Orbits	~3 cm	3–9 h	At 03, 09, 15, 21 UTC	15 min
	Sat. clocks	~150 ps RMS ~50 ps SDev			
Rapid	Orbits	~2.5 cm	17–41 h	At 17 UTC daily	15 min
	Sat. and Stn. clocks	~75 ps RMS ~25 ps SDev			5 min
Final	Orbits	~2.5 cm	12–18 days	Every Thursday	15 min
	Sat. and Stn. clocks	~75 ps RMS ~20 ps SDev			Sat.: 30s Stn.:5 min

Table 1. Accurate GPS satellite orbits and clock corrections issued by IGS.

the wavelength; ε_p and ε_φ are the noise components including the signal reflection [5, 6]. The geometric distance between satellite (X^S, Y^S, Z^S) and receiver (X_R, Y_R, Z_R) is defined as:

$$\rho = \sqrt{(X^S - X_R)^2 + (Y^S - Y_R)^2 + (Z^S - Z_R)^2} \tag{2}$$

PPP technology has different software options such as Bernese, Gamit, GIPSY/OASIS II to determine the position.

3. GNSS measurements processing software

Today, we can classify software that can evaluate GNSS measurements in three different groups. The first of these is commercial software. Commercial software is a software that is bundled with the GNSS set, which is often used in practical engineering applications and is usually purchased by customer companies. These are the more preferred software by institutions and organizations that best determine the solutions offered by the company in order to avoid any problems from the users. Other software that can process GNSS measurements are scientific software. Scientific software has been fully developed at research centers and universities for use in academic and scientific studies. The use of scientific software is more complex than commercial software and web-based data processing services. For this reason, there are

PPP service name	Organizations	Web pages (March, 2018)
CSRS-PPP: Canadian Spatial Reference System- Precise Point Positioning	Natural Resources Canada (NRC)	https://webapp.geod.nrcan.gc.ca/geod/tools-outils/ppp.php?locale=en
GAPS: GPS Analysis and Positioning Software	University of New Brunswick (UNB)	http://gaps.gge.unb.ca/submitadvanced.php
APPS: Automatic Precise Positioning Service	NASA- Jet Propulsion Laboratory (JPL)	http://apps.gdgps.net/apps_file_upload.php
magicGNSS: magic Precise Point Positioning Solution	GMV Aerospace and Defence S.A.U.	https://magicgnss.gmv.com/user/ppp

Table 2. Online services using PPP solution approach.

more training-, information-, and experience-related requirements. In such software, different parameters used in the evaluation can provide a different significance in the results. A third type of software that can process GNSS observations is web-based positioning services. In this service, it is necessary to have only one GNSS receiver and an Internet connection in order to be able to generate the point position information if the observations in the GNSS receiver are aggregated in whatever manner the observations are aggregated in static or kinematic methods. There is no need for any additional financing or equipment other than these equipment. Web-based GNSS services are simple to use and require no additional software knowledge. The data in the RINEX format obtained from the GNSS receivers are processed by uploading them to the web interface of web-based positioning services. Depending on the service to be used, some services require additional information such as the receiving antenna brand and antenna height. At the end of the evaluation process initiated after the uploading process of the GNSS observations, the final report of the relevant GNSS observations is presented to the user via e-mail or a link that can be downloaded from the web interface. The Internet addresses of the web-based positioning services that can process GNSS observations according to the PPP method and provide them to the users are given in **Table 2**.

All of the services mentioned in **Table 2** have limited use. However, they use scientific and academic software in the background to determine the station coordinates. These services present the resultant product using the commonly accepted parameters of the data processing methods for coordinate production from GNSS observations in the literature. The web-based positioning services used in this study are:

3.1. CSRS-PPP: Canadian spatial reference system-precise point positioning

Canadian Spatial Reference System Precise Point Positioning (CSRS-PPP) is a web-based GPS observations processing service provided by the Natural Resources Canada (NRCAN). This service works with a membership system that has the ability to process GNSS observations from single- or dual-frequency receivers based on static or PPP techniques. CSRS-PPP uses precise GPS orbit and clock products provided by the IGS. The solutions of PPP coordinates are represented in both NAD83 and ITRF14 data with detailed graphical analysis reports. This service has actively processed GLONASS data from October 4, 2011 and accepted user-provided ocean tidal loading (OTL) correction files from February 14, 2012.

3.2. GAPS: GPS analysis and positioning software

GPS analysis and positioning software (GAPS) is a web-based processing service for GPS observations provided by the University of New Brunswick (UNB). It is a service that does not require membership registration. This service uses IGS's rapid and final orbit and clock products during the process of GPS observations. GAPS is a service that delivers GNSS solutions to users via e-mail. The coordinate solutions of GAPS are represented in ITRF14 datum.

3.3. APPS: automatic precise positioning service

Automatic precise positioning service (APPS) is a web-based GPS evaluation service operated by NASA Jet Propulsion Laboratory (JPL) and the California Institute of Technology. In the background of this service, the scientific software GIPSY/OASIS II developed in this institution is also run. The system also uses real-time, daily and weekly GPS orbit and clock products produced by JPL. The results of the evaluation can be obtained shortly after the options in the service interface (antenna height, antenna type, e-mail address, etc.) are checked and the GNSS observations are loaded. The solutions of PPP coordinates are represented in ITRF08 datum with detailed analysis reports. APPS is a web-based positioning service that requires membership and offers the use of ftp services for industrial users.

3.4. MagicGNSS: magic precise point positioning solution

Magic Precise Point Positioning Solution is an Internet service created by Spanish GMV Company. MagicGNSS is a positioning service that uses accurate positioning detection technology. The most important advantage of the service is that it can analyze GPS and GLONASS observations together. This system can process both static and kinematic observations. The PPP module of this service uses accurate clock and precise orbit products which are provided by the IGS. The system supports RINEX and all compressed observation formats and offers free 1-GB disk space for member users. The service provides users with a detailed graphical analysis report along with positioning solutions. The solutions of PPP methods are represented in both ETRS89 and ITRF14 data. The service works by downloading or e-mailing the result files from the service's Internet interface.

4. Experimental study

This study provides the accuracy analysis of the web-based online services using PPP solution approaches. For this purpose, HRUH permanent reference station which located on top of the roof of Geomatics Engineering Department's GNSS Laboratory in Harran University

HRUH GNSS station	$X(m)$	$Y(m)$	$Z(m)$
Observation duration	$\sigma_X(m)$	$\sigma_Y(m)$	$\sigma_Z(m)$
1 h	3,954,667.2472	3,202,680.8771	3,833,020.8337
	0.0460	0.0386	0.0347
2 h	3,954,667.2465	3,202,680.8640	3,833,020.8351
	0.0065	0.0065	0.0060
6 h	3,954,667.2430	3,202,680.8621	3,833,020.8269
	0.0035	0.0031	0.0031
12 h	3,954,667.2426	3,202,680.8609	3,833,020.8263
	0.0025	0.0022	0.0023
24 h	3,954,667.2418	3,202,680.8605	3,833,020.8310
	0.0018	0.0015	0.0016

Table 3. HRUH station hourly coordinates and standard deviations.

was selected for the accuracy analysis. The GPS data segmented into 1-, 2-, 6-, 12-, and 24-h sessions were collected by HRUH station in static mode on April 18, 2018 (DOY 108). The data sampling interval of the GNSS receiver was 30 s. As a result of this study, we have compared the analysis results obtained by using CSRS-PPP, GAPS, APPS, MagicGNSS services, and scientific software (GIPSY/OASIS II) which produce solutions based on PPP technique. All services including GIPSY/OASIS II scientific software (except APPS) use coordinate solutions at ITRF14 datum. In order to be able to compare the analysis results of all services in the same datum, APPS coordinate solutions in ITRF08 datum have been converted to the coordinates of ITRF14 datum with the help of URL [7]. **Table 3** gives the coordinates and standard deviation results in the Cartesian coordinate system according to the 1-, 2-, 6-, 12-, and 24-h GPS observations of the HRUH station with GIPSY/OASIS II scientific software.

The aim of the study was to determine how consistent results from web-based positioning services are. GPS observations for 1-, 2-, 6,- 12-, and 24-h on the same day (DOY 108) belonging to the same station were separated and loaded into each individual web-based positioning system and results were obtained. Apart from the results obtained during the 1-h observation period, the best coordinate precision and accuracy are understood from the results of the APPS service. The consistency between the GIPSY/OASIS II scientific software and the solutions of the GAPS web-based positioning systems is close together. MagicGNSS service provides only the coordinate points, the related standard deviations are not added to the figures. **Figures 2–6** show the results of the coordinates and standard deviation values of the Cartesian coordinate system for 1-, 2-, 6-, 12-, and 24-h GPS observations of the HRUH station produced by the web-based positioning services, respectively.

When the solutions of 1-h GPS observations of the HRUH station in **Figure 2** are examined, the standard deviation values for the CSRS-PPP, GAPS, APPS, and GIPSY/OASIS II coordinate solutions range from 0.01 to 0.1 m. Standard deviation values of the coordinate components

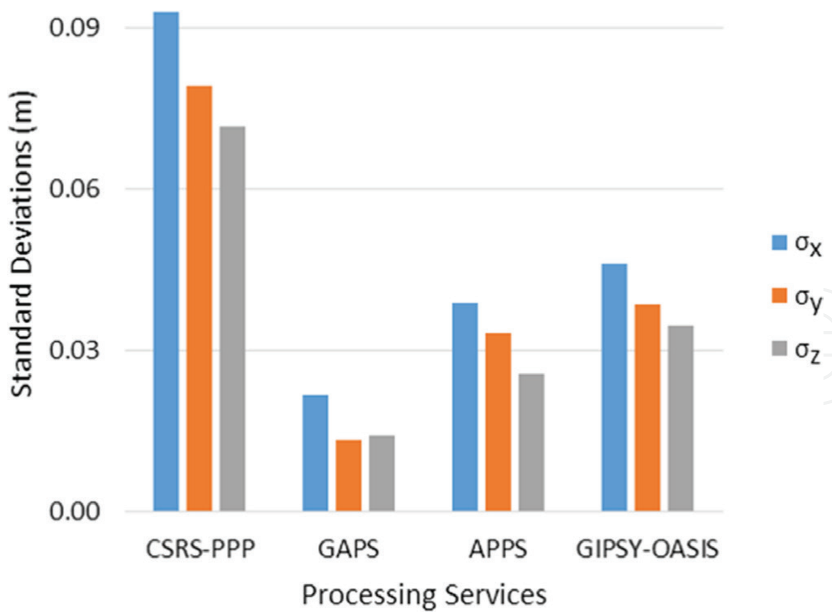

Figure 2. Standard deviations of HRUH station coordinates (1 h).

obtained from the CSRS-PPP service were determined as σ_x = ±0.092 m, σ_y = ±0.079 m, and σ_z = ±0.071 m, respectively. Standard deviation values of the coordinate components obtained from the GAPS service are σ_x = ±0.021 m, σ_y = ±0.033 m, and σ_z = ±0.026 m, respectively, and the standard deviation values of the coordinate components obtained from the APPS service are σ_x = ±0.038 m, σ_y = ±0.033 m, and σ_z = ±0.026 m. Standard deviation values of the coordinate components obtained by GIPSY/OASIS II scientific software are calculated as σ_x = ±0.046 m, σ_y = ±0.038 m, and σ_z = ±0.034 m, respectively.

When the solutions of the 2-h GPS observations of the HRUH station in **Figure 3** are examined, the standard deviation values of the CSRS-PPP, GAPS, APPS, and GIPSY/OASIS II coordinate solutions range from 0.005 to 0.056 m. Standard deviation values of the coordinate components obtained from the CSRS-PPP service were determined as σ_x = ±0.056 m, σ_y = ±0.035 m, and σ_z = ±0.037 m, respectively. Standard deviation values of coordinate components obtained from GAPS service are σ_x = ±0.014 m, σ_y = ±0.006 m, and σ_z = ±0.008 m, respectively and the standard deviation values of coordinate components obtained from APPS service are σ_x = ±0.005 m, σ_y = ±0.005 m, and σ_z = ±0.005 m. Standard deviation values of the coordinate components obtained by GIPSY/OASIS II scientific software were calculated as σ_x = ±0.006 m, σ_y = ±0.006 m, and σ_z = ±0.006 m, respectively.

When the solutions of the 6-h GPS observations of the HRUH station in **Figure 4** are examined, the standard deviation values for the CSRS-PPP, GAPS, APPS, and GIPSY/OASIS II coordinate solutions range from 0.002 to 0.027 m. Standard deviation values of the coordinate components obtained from CSRS-PPP service were determined as σ_x = ±0.027 m, σ_y = ±0.017 m, and σ_z = ±0.018 m, respectively. Standard deviation values of coordinate components obtained from GAPS service are σ_x = ±0.005 m, σ_y = ±0.003 m, and σ_z = ±0.003 m, respectively, and the standard deviation values of coordinate components obtained from APPS service are σ_x = ±0.003 m, σ_y = ±0.003 m, and σ_z = ±0.003 m. Standard deviation values of the coordinate components obtained by GIPSY/OASIS II scientific software were calculated as σ_x = ±0.003 m, σ_y = ±0.003 m, and σ_z = ±0.003 m, respectively.

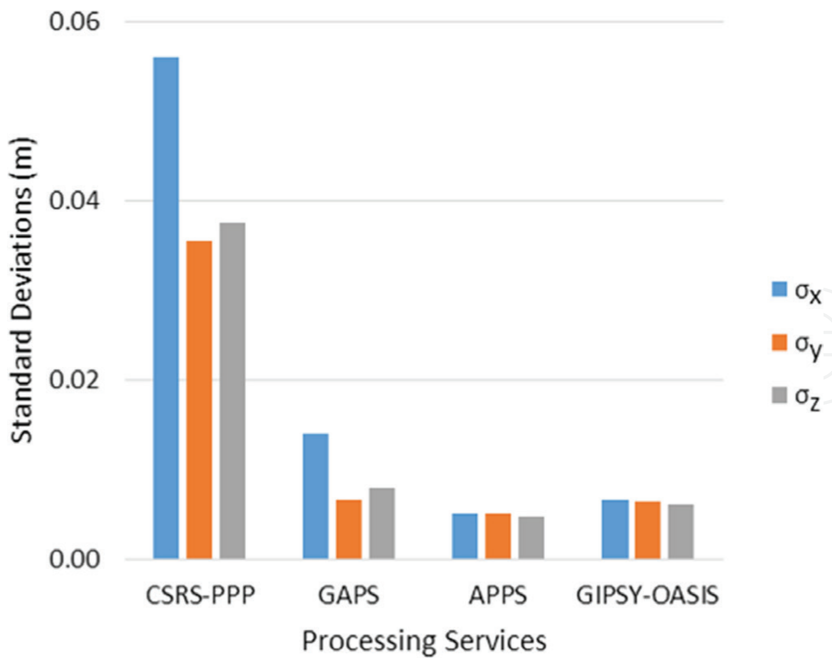

Figure 3. Standard deviations of HRUH station coordinates (2 h).

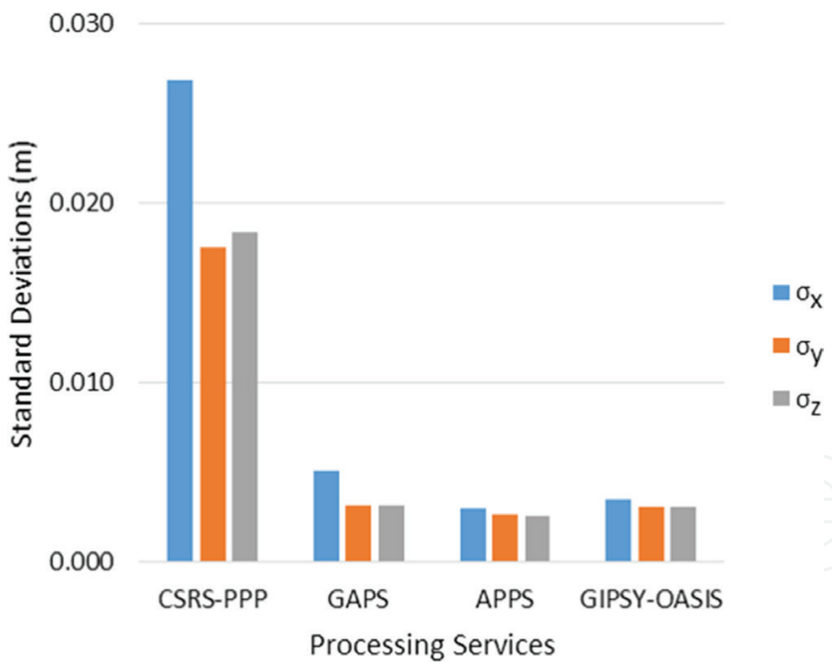

Figure 4. Standard deviations of HRUH station coordinates (6 h).

When the solutions of the 12-h GPS observations of the HRUH station are examined in **Figure 5**, the standard deviation values of the CSRS-PPP, GAPS, APPS, and GIPSY/OASIS II coordinate solutions range from 0.002 to 0.015 m. Standard deviation values of the coordinate components obtained from the CSRS-PPP service were determined as $\sigma_x = \pm 0.0147$ m, $\sigma_y = \pm 0.0128$ m, and $\sigma_z = \pm 0.0125$ m, respectively. Standard deviation values of coordinate components obtained from GAPS service are $\sigma_x = \pm 0.0026$ m, $\sigma_y = \pm 0.0024$ m, and $\sigma_z = \pm 0.0021$ m,

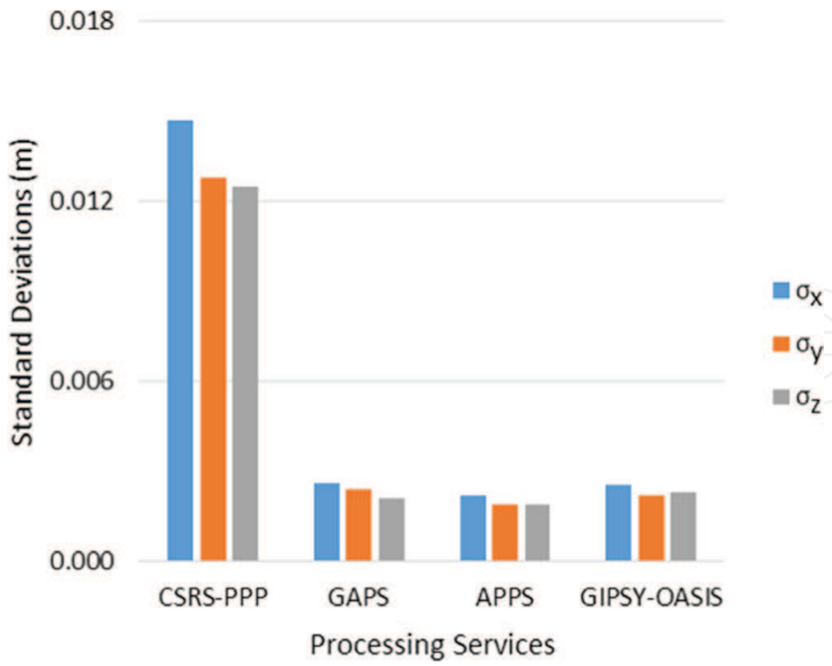

Figure 5. Standard deviations of HRUH station coordinates (12 h).

respectively, and the standard deviation values of coordinate components obtained from APPS service are $\sigma_x = \pm 0.0022$ m, $\sigma_y = \pm 0.0019$ m, and $\sigma_z = \pm 0.0019$ m. Standard deviation values of the coordinate components obtained by GIPSY/OASIS II scientific software are calculated as $\sigma_x = \pm 0.0025$ m, $\sigma_y = \pm 0.0022$ m, and $\sigma_z = \pm 0.0023$ m, respectively.

When the solutions of the 24-h GPS observations of the HRUH station are examined in **Figure 6**, the standard deviation values of the CSRS-PPP, GAPS, APPS, and GIPSY/OASIS II coordinate solutions range from 0.001 to 0.009 m. Standard deviation values of the coordinate components obtained from CSRS-PPP service were determined as $\sigma_x = \pm 0.0096$ m, $\sigma_y = \pm 0.0086$ m, and $\sigma_z = \pm 0.0084$ m, respectively. Standard deviation values of coordinate components obtained from GAPS service are $\sigma_x = \pm 0.0017$ m, $\sigma_y = \pm 0.0015$ m, and $\sigma_z = \pm 0.0015$ m, respectively, and the standard deviation values of coordinate components obtained from APPS service are $\sigma_x = \pm 0.0015$ m, $\sigma_y = \pm 0.0013$ m, and $\sigma_z = \pm 0.0014$ m. Standard deviation values of the coordinate components obtained by GIPSY/OASIS II scientific software are calculated as $\sigma_x = \pm 0.0018$ m, $\sigma_y = \pm 0.0015$ m, and $\sigma_z = \pm 0.0016$ m, respectively.

If the result in **Figures 2–6** will be interpreted graphically, the most sensitive results for the results of different observation periods of each coordinate component evaluated in the web-based positioning services are GAPS service for 1 h observation period; APPS service for 2-, 6-, 12-, and 24-h observation periods. The CSRS-PPP service was at the forefront of all evaluations.

After obtaining the standard deviations of each coordinate component in the Cartesian coordinate system of the web-based positioning services, the obtained coordinates were compared with the coordinates obtained in GIPSY/OASIS II scientific software. The calculated web-based coordinate results were subtracted from the coordinates obtained from GIPSY/OASIS II scientific software and classified according to web-based positioning services and GPS observation times (**Figures 7–10**).

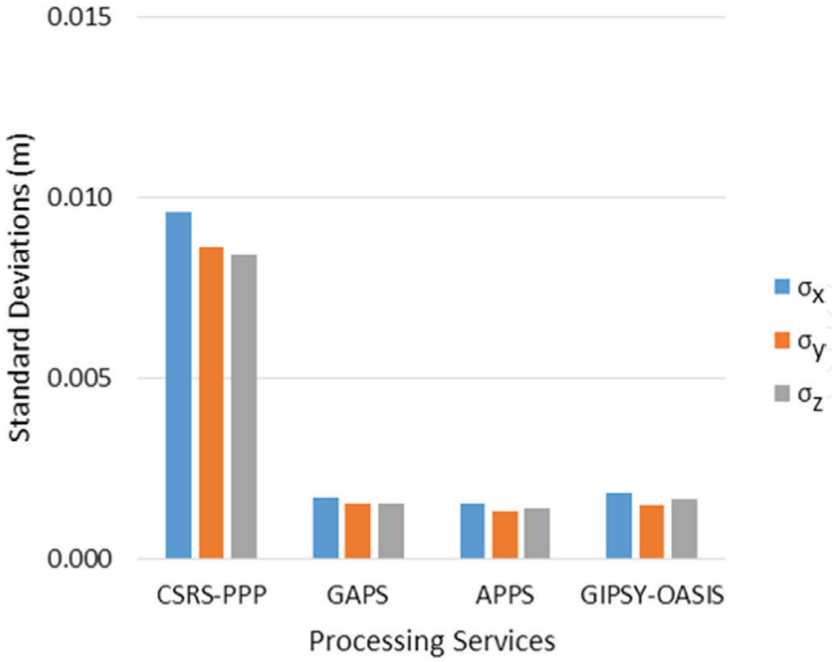

Figure 6. Standard deviations of HRUH station coordinates (24 h).

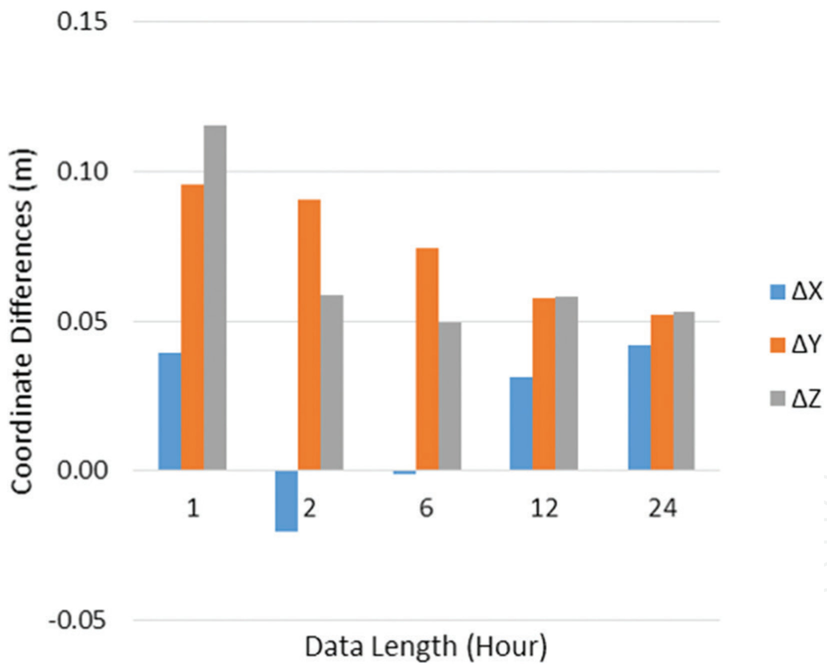

Figure 7. Coordinate differences between CSRS-PPP solution and GIPSY/OASIS II solution.

In **Figure 7**, the differences between the CSRS-PPP web-based positioning service and the coordinate solutions of different GPS observation times obtained by the GIPSY/OASIS II scientific software are calculated. The differences of the coordinate solutions of 1 h GPS observation time are calculated as $\Delta X = 0.039$ m, $\Delta Y = 0.095$ m, and $\Delta Z = 0.115$ m. The differences of the coordinate solutions of the 2-h GPS observation time were calculated as $\Delta X = -0.020$ m, $\Delta Y = 0.091$ m, and $\Delta Z = 0.058$ m. The differences of the coordinate solutions of the 6-h GPS observation

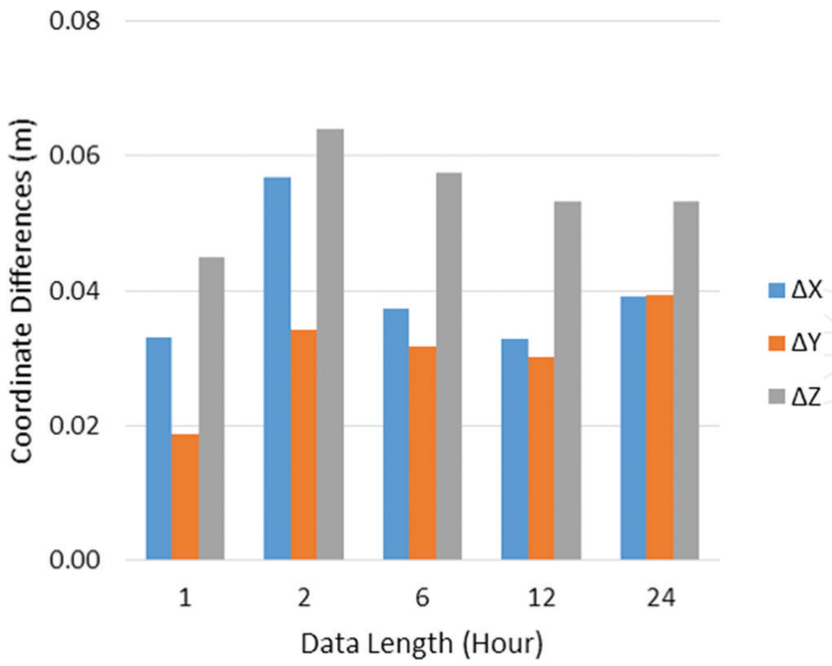

Figure 8. Coordinate differences between GAPS solution and GIPSY/OASIS II solution.

period were calculated as ΔX = −0.001 m, ΔY = 0.074 m, and ΔZ = 0.049 m. The differences of the coordinate solutions of the 12-h GPS observation period were calculated as ΔX = 0.031 m, ΔY = 0.058 m, and ΔZ = 0.058 m. The differences of the coordinate solutions for the 24-h GPS observation period were calculated as ΔX = 0.042 m, ΔY = 0.052 m, and ΔZ = 0.053 m.

In **Figure 8**, the differences between the GAPS web-based positioning service and the coordinate solutions of different GPS observation times obtained by the GIPSY/OASIS II scientific software are calculated. The differences of the coordinate solutions of the 1 h GPS observation period were calculated as ΔX = 0.033 m, ΔY = 0.019 m, and ΔZ = 0.045 m. The differences in coordinate solutions for the 2-h GPS observation period were calculated as ΔX = 0.058 m, ΔY = 0.034 m, and ΔZ = 0.064 m. The differences of the coordinate solutions of the 6-h GPS observation period were calculated as ΔX = 0.037 m, ΔY = 0.032 m, and ΔZ = 0.057 m. The differences of the coordinate solutions of the 12-h GPS observation period were calculated as ΔX = 0.033 m, ΔY = 0.030 m, and ΔZ = 0.053 m. The differences of coordinate solutions for the 24-h GPS observation period were calculated as ΔX = 0.039 m, ΔY = 0.039 m, and ΔZ = 0.053 m.

In **Figure 9**, the differences between the coordinate solutions of different GPS observation times obtained by the APPS web-based positioning service and GIPSY/OASIS II scientific software are calculated. The differences of the coordinate solutions of 1 h GPS observation time are calculated as ΔX = 0.050 m, ΔY = 0.008 m, and ΔZ = 0.039 m. The differences of the coordinate solutions of the 2-h GPS observation period were calculated as ΔX = 0.054 m, ΔY = 0.040 m, and ΔZ = 0.055 m. The differences of the coordinate solutions of the 6-h GPS observation period were calculated as ΔX = 0.052 m, ΔY = 0.042 m, and ΔZ = 0.054 m. The differences of the coordinate solutions for the 12-h GPS observation period were calculated as ΔX = 0.048 m, ΔY = 0.039 m, and ΔZ = 0.052 m. The differences in the coordinate solutions of the 24-h GPS observation period were calculated as ΔX = 0.048 m, ΔY = 0.040 m, and ΔZ = 0.053 m.

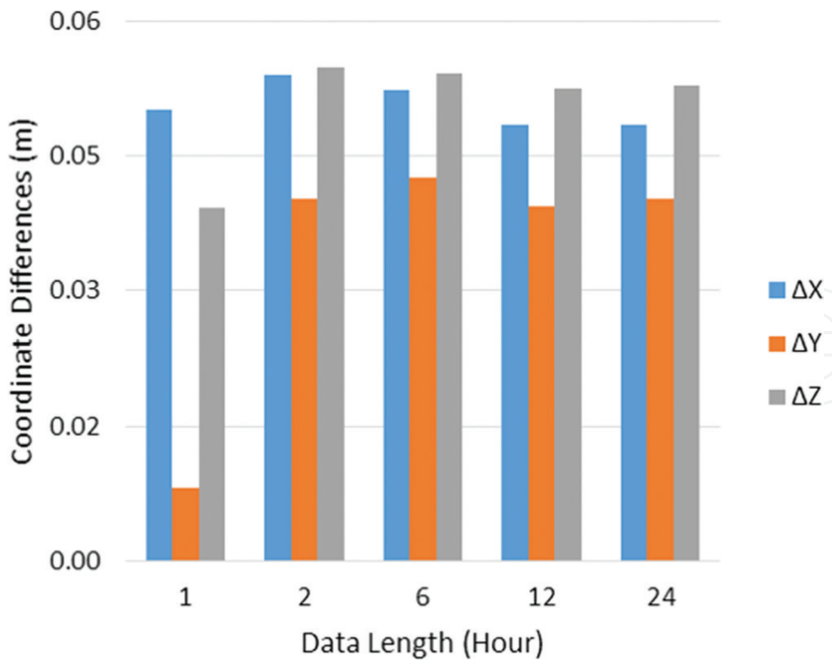

Figure 9. Coordinate differences between APPS solution and GIPSY/OASIS II solution.

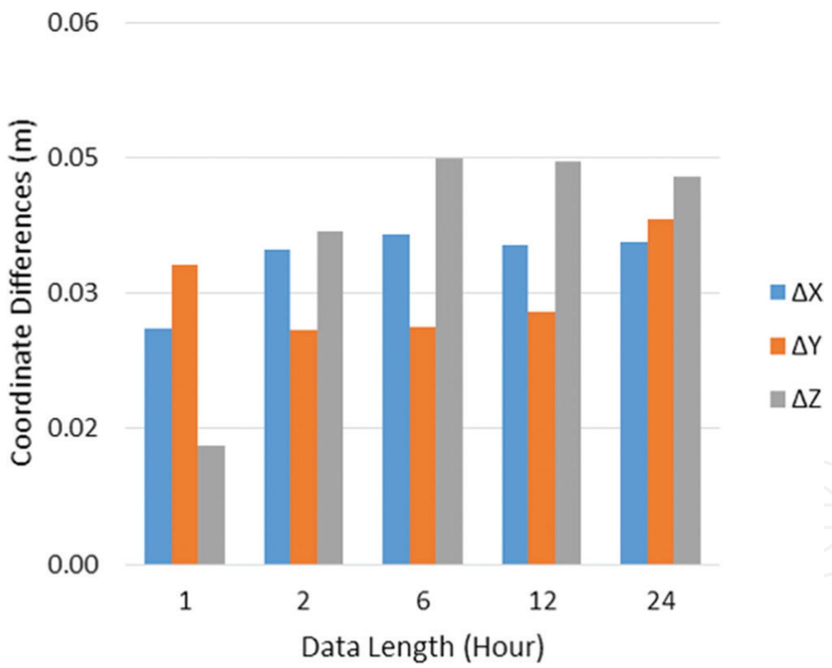

Figure 10. Coordinate differences between MagicGNSS solution and GIPSY/OASIS II solution.

In **Figure 10** the differences between the coordinate solutions of different GPS observation times obtained by the MagicGNSS web-based positioning service and GIPSY-OASIS scientific software are calculated. The differences of the coordinate solutions of 1 h GPS observation time are calculated as $\Delta X = 0.026$ m, $\Delta Y = 0.033$ m, and $\Delta Z = 0.013$ m. The differences of coordinate solutions for the 2-h GPS observation time are calculated as $\Delta X = 0.035$ m, $\Delta Y = 0.026$ m, and ΔZ = 0.037 m. The differences of the coordinate solutions of the 6-h GPS observation period were calculated as ΔX = 0.036 m, ΔY = 0.026 m, and ΔZ = 0.045 m. The differences in coordinate solutions for the 12-h GPS observation period were calculated as ΔX = 0.035 m, ΔY = 0.028 m, and ΔZ = 0.045 m. The differences of the coordinate solutions of the 24-h GPS observation period were calculated as ΔX = 0.035 m, ΔY = 0.038 m, and ΔZ = 0.043 m.

APPS uses GIPSY/OASIS II in the background. However, the difference in the results between GIPSY/OASIS II and APPS is slightly larger than the difference in results between GIPSY/OASIS II and MagicGNSS. This can be ascribed to the fact that APPS results are based on the ITRF08 but not the ITRF14 on which both GIPSY/OASIS II and MagicGNSS rely.

In **Figures 7–10**, the differences between the coordinate values of the HRUH permanent GNSS station produced by the web-based positioning services for different GPS observation times and the coordinate solutions obtained by the GIPSY/OASIS II scientific software are examined.

In **Figure 7**, when the coordinate solutions obtained from the CSRS-PPP web-based positioning service are compared with the coordinate solutions obtained from the GIPSY/OASIS II scientific software, the coordinate differences between 1- and 2-h observation periods are found to be around 10 cm, coordinate differences for 6- and 12-h observation periods are around 5 cm, and for 24-h observation periods, coordinate differences are less than 5 cm.

In **Figure 8**, when the coordinate solutions obtained from the GAPS web-based positioning service are compared with the coordinate solutions obtained from the GIPSY/OASIS II scientific software, the coordinate differences between 1-h observation period is found to be less than 5 cm, coordinate differences for 2-, 6-, 12-, and 24-h observation periods are around 5 cm.

In **Figure 9**, when the coordinate solutions obtained from the APPS web-based positioning service are compared with the coordinate solutions obtained from the GIPSY/OASIS II scientific software, the coordinate differences between 1-h observation period is found to be less than 5 cm, coordinate differences for 2-, 6-, 12-, and 24-h observation periods are around 5 cm.

In **Figure 10**, when the coordinate solutions obtained from the MagicGNSS web-based positioning service are compared with the coordinate solutions obtained from the GIPSY/OASIS II scientific software, the coordinate differences between 1-, 2-, 6-, 12-, and 24-h observation period is found to be less than 5 cm.

5. Conclusion

Today, PPP technology is becoming increasingly important. With its many advantages, it poses a serious alternative to positioning methods. However, the use of web-based positioning services, which analyze using PPP technology, is becoming widespread. The PPP technique is feasible in the measurement and evaluation process with only one GNSS receiver, and providing these services to the user free of charge on the Internet makes these systems advantageous in many applications. It should not be forgotten that the reliability of the results evaluated according to the PPP technique is directly related to the accuracy of the IGS orbit and clock information.

In such systems, many outcome products can be obtained without the need for GNSS expertise other than basic level. When using web-based positioning services, choosing the solution parameters appropriate to the data structure and the measurement method can bring the coordinate accuracy to the highest level. Applications for scientific research should indicate that such services are not suitable for applications that require expertise, such as ionospheric and tropospheric models, deformation analysis studies, earth orientation parameters, and so on.

The results from web-based location services show that there is not much difference between the results of software that solves with scientific PPP technique when there is enough observation period in GNSS sessions. This is rather obvious in the precision results given in **Figures 2–6**. In the application where PPP services are evaluated, it is seen that the results are directly related to the observation period. Accuracy is increased by increasing the observation time from 1 to 24 h, but the results are still at several centimeters. Precision results given in **Figures 2–6** are very similar to those published by the IGS. In order to be able to obtain accuracy results similar to those of precision results, one needs to adopt equal processing strategy for all software used here but unfortunately this was impossible throughout this study.

The user needs to select the observation period on the point according to the expected accuracy level. The results obtained from such services, which provide a great gain in terms of time and cost, are sufficient to give the position information for many engineering applications.

Acknowledgements

The author thanks to International GNSS Service (IGS) for product supports, and to organizations, which present web-based online services (CSRS-PPP, GAPS, APPS, MagicGNSS). Special thanks to Research Assistants Ali Hasan DOĞAN and Mustafa Fahri KARABULUT in Yildiz Technical University (YTU) for their help in assisting at the post processing stage of GPS observations by using GIPSY-OASIS II scientific software with PPP technique. NASA JPL's software GIPSY/OASIS II is licensed to Department of Geomatic Engineering of YTU.

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